

Artificial Reefs v. Natural Reefs

the potential of Windmill farms as Artificial Reef



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Abstract

Artificial reefs fulfill many different functions: fish aggregation devices, diving hot spots and as conservation tool to revitalize a marine ecosystem. The foundations of windmills offer a great opportunity to function as an artificial reef. However, wind farms have a variety of possible impacts on a marine environment. Furthermore, for artificial reefs to utilize its maximum potential in providing a habitat for local biota, it must simulate fringing natural reefs. To achieve this it is important to understand how habitat structure influences the biota. The present thesis reviews four different papers dealing with natural vs. artificial reefs. Comparison was done of fish communities between artificial reefs and natural reefs. In terms of fish abundance and species richness, artificial reefs showed little difference to natural reefs. Species composition varied throughout all the studies. Habitat complexity is the determining factor in species composition and species richness, explaining 71% of the variance. Results suggest that in order to simulate communities similar to that of natural reefs, one must create a similar complex habitat.

Introduction

Flooded coastal cities and sunken vessels were one of the first non-natural hard substrates functioning as a reef in marine ecosystems. Although their function as artificial substrates was unintentional, these underwater structures provided a hard underground where natural substratum was lacking. Artificial reefs (AR) are useful to marine organisms on a local scale in coastal waters that are barren and devoid of life. In present day, many structures are intentionally placed in coastal systems to function as ARs. These ARs have different sizes and shapes, varying between old sunken ships, perforated concrete balls, concrete blocks, breakwaters, tires, trams, oil rigs and derelict vessels (Baine, 2001).

Since the 1700's ARs have been constructed and/or placed deliberately with the purpose to increase fishing yield (Ino, 1974; Stone, 1984). Their use as a tool for fisheries management still continues till this day. But in last three decades, ARs also fulfill other distinct functions. With the rise of the sport diving industry, ARs have achieved an aesthetic value; by attracting tourists, these diving hotspots also provide a source of income (Brock, 1994). Furthermore, the use of ARs as a tool in conservation biology in order to protect and/or revitalize coastal ecosystems is recognized (Claudet and Pelletier, 2004; Lan and Hsui, 2005). For all of the above reasons ARs are used on a global scale, their occupancy ranges from tropical to sub arctic coastal systems (Baine, 2001).

Although the efficacy of ARs has been established by their application on a global scale and the wide variety of forms available, what governs their success is still under examination. One of the key factors identified thus far is structural complexity, i.e. habitat complexity (Ferreira *et al.*, 2001; Gratwicke and Speight, 2005; Wen *et al.*, 2010). In general, complex structures can be defined as consisting out of many different and intricately connected parts. For example, in ARs crevices and holes provide microhabitats for a variety of organisms hereby fulfilling an important biological and ecological function as they are necessary for species recruitment, colonization, and protection from predation (Bulleri, 2005; Wen *et al.*, 2010). However, unlike natural rocky substrata, i.e. natural reefs (NR), most anthropogenic structures are smoother and have less relief (Wen *et al.*, 2010). The lack in structural complexity of ARs is thought to be reflected in their incapability of maintaining similar amounts of biomass, species diversity and species assemblage as NRs (Gratwicke and Speight, 2005).

A potential AR in marine ecosystems are the foundations of offshore wind farms. With the rising demand of renewable energy sources, wind farms are a great alternative source of energy and are being applied globally. The act of harnessing wind as an energy source is environmentally benign, but they have also been the subject of extensive scrutiny (Michel *et al.*, 2007). Wind farms offer an environmentally safe and sustainable alternative to fossil fuels, but they can not only disrupt but permanently damage a pristine marine ecosystem.

The potential that offshore wind farms offer as an AR is a fine balance between the negative and positive effects it has on marine ecosystems. If offshore wind farms are placed in an inappropriate sitting, such as a pristine ecosystem, they cause significant habitat loss and deleterious effects to certain taxa (Inger *et al.*, 2009). The collision risks of offshore wind farms have not yet been thoroughly examined. It seems unlikely that these large and static structures present a risk to submarine organisms. Although submerged cables, chains and power lines pose a greater risk, as they are less visible, and sometimes free moving in the water column. Also, underwater light sources have the potential to attract marine organisms, increasing the risk of collision (Marchesan *et al.*, 2006). Another potential impact on marine organisms is anthropogenic noise and underwater vibrations. The introduction of extra noise is likely to impact local marine life (Thomson *et al.*, 2006), especially those sensitive to acoustics such as marine mammals (Nowacek *et al.*, 2007). Finally the electromagnetic fields produced by the power cables going to and from the offshore wind farms also present a danger to marine life. The electromagnetic fields have the potential to affect magnetic sensitive fish and turtle species (Luschi *et al.*, 2007; Gould, 2008).

None the less, offshore wind farms offer a great opportunity to simultaneously be used as renewable source of energy and, if managed, planned, placed and executed well, exploit its potential as an AR (Inger *et al.*, 2009).

The foundations of wind turbines are slabs of concrete on the ocean floor. These slabs provide a structural foundation for the wind turbines, but lack structural complexity. Simply the presence of hard substrata in an otherwise barren landscape offers benthic and pelagic organisms a habitat. But if ARs are to achieve the similar species composition and biomass, ARs must mimic surrounding NRs in their design. One can then simulate the conditions of NRs, by creating a complex habitat. Since habitat complexity implies that substrata are not made out of simple definable building blocks, it becomes a meticulous job to make a distinction of how ARs influence biotic processes in coastal ecosystems. In order to assess the possibilities of using the foundations of offshore wind farms as ARs, one must first understand the structural components that influence the presence, composition and diversity of marine organisms on NRs.

The aim of this review is 1) to provide a critical view on the differences in species composition, abundance and biomass between ARs and NRs, and to 2) critically assess the use of off-shore wind farms as an artificial reef.

Analyses artificial reefs v. natural reefs

Artificial reefs are colonized rapidly and tend to develop fish and benthic communities that are similar to that of fringing natural reefs (Perkol-Finkel and Benayahu 2004). However, a generalization is not possible because other studies have shown that differences do occur between communities of AR and NR (Rilov and Benayahu 2000). A comparison between AR and NR is a necessity in order to understand their role in the marine environment. Comparison studies can provide valuable information on the species composition and abundance and this in turn can lead to an understanding of community structuring. If offshore wind mill farms are to simulate NRs, the structural factors affecting community structures should resemble NRs in order for them to perform as a conservation tool. Below follows three comparison studies between ARs and NRs (Table I). They are all focused on comparing the structure of fish communities on ARs and NRs, using variables as fish abundance, fish diversity, species richness and fish assemblages as indicators which could vary on a temporal scale and per habitat. Since fish inhabit many different niches (e.g. pelagic or benthic), can be found on many different trophic levels and have different locations on the food web (ranging from herbivores to piscivores) they are an excellent species to use in order to gain an understanding in the community structuring of reefs. Fish can be used as a reflection of the system.

Abundance

Wen *et al.* (2010) showed that there was no significant difference in fish abundance between artificial v. natural habitats, although they did vary among locations and seasons (i.e. summer and winter). In 2 out of the 5 locations where fieldwork was conducted, fish abundance was significantly higher in the summer, and in 1 out of the 5 locations winter was significantly higher. Wen *et al.* (2010) showed a seasonal variation, but in the paper of Arena *et al.* (2007) such evidence was lacking, thus showing no significant temporal variance. However mean fish abundance on ARs was significantly greater than on NRs (Arena *et al.* 2007). Furthermore, the dominant species on ARs and NRs were different: 46% of total fish

abundance was consisting out of the *Haemulidae* family, and on natural reefs 25% of total fish abundance was compromised out of the *Labridae* family. In terms of biomass ARs also showed a significantly greater amount than NRs (Arena *et al.* 2007).

Table I. Authors, description of the artificial and natural reef, used methods to inventory fish abundance and species richness, measured variables, applied statistical analyses, results relevant to this thesis, and a reference to figure or table in the actual publication. * = $P < 0.05$.

Author	Habitat	Method	Variable	Statistical Analyses	Results	Figure/ Table
Wen <i>et al.</i> (2010)	AR= Breakwaters, NR= rocky reefs & coral reefs	Underwater Visual Census. Per site; Three replicate 10m transects at least 2m apart along 4m depth contour.	Var. abund. & spec richness fish; Between NR v. AR, among local, and between season	Three-way ANOVA	Variance in abundance AR v. NR	Table I
					Abundance summer v. winter 3 out of 5 sites *	Fig. 1.
					Spec richness summer v. winter	Table II
					Spec richness AR v. NR	Table II
					Spec richness among AR	Table II
					Var. Taxonomic comp. fish assemblages; between NR v. AR among local, and between season	MANOVA with Pillai's trace test statistic
				Fish assemblages AR v. NR *	Table III	
				Fish assemblages between locations *	Table III	
Burt <i>et al.</i> (2009)	AR= Breakwaters, NR= coral reefs	Underwater Visual Census. Per site; Twelve replicate 30m transects	Fish assemblages: AR v. NR and between season	Ordination and Vectors	Fish assemblages AR v. NR; 49% explained by habitat type *	Fig. 4a.
					Var. fish assemblages over the year *	Fig. 4b.
			Var. abund. & spec richness fish; Between AR v. NR, and between season	One/Two-way ANOVAs; Pair-wise Shannon Wiener diversity <i>t</i> -test	Spec richness fish AR v. NR	Table II
					Var. in spec richness fish over the year *	Fig. 3.
					Shannon Wiener diversity within year and among habitats	
					Var. fish juveniles and piscivores; between AR v. NR and between season	One/Two-way ANOVAs; Pair-wise Shannon Wiener diversity <i>t</i> -test
				Increase Juveniles in Summer for AR and NR *	Fig. 6a.	
				Increase Adult in Summer only on AR *	Fig. 6c.	
				Piscivores AR > NR (difference biggest in fall) *	Fig. 7b.	
Arena <i>et al.</i> (2007)	AR = Vessel, NR= relic coral	Underwater Visual Census. Per site; 15m diameter cylinder	Var. fish abund., biomass, spec richness; Between AR v. NR	ANOVA and post-hoc Tukey-Kramer	Abundance AR > NR *	Table II
					Spec richness AR > NR *	Table II
			Trophic preference	ANOVA and post-hoc Tukey-Kramer	Juvenile AR > NR *	Fig. 2.
					Planktivores AR > NR *	Fig. 3.
					Benthic Carnivores AR > NR *	Fig. 3.
					Herbivores AR < NR *	Fig. 3.
				Piscivores AR > NR *	Fig. 3.	
		Assemblage Structure	Multidimensional scaling, ANOSIM and SIMPER analysis	AR v. NR. Little overlap *	Fig. 5.	
				Highest dissimilarity found between oldest and youngest AR		

Species richness

The study of Burt *et al.* (2009) showed that although ARs contained a higher total number of fish species throughout the sampling period, mean richness and Shannon-Wiener diversity did not differ between ARs and NRs. Artificial reefs showed a temporal variation, whereas species richness on NRs was stable throughout the sampling period. Artificial reefs had significantly higher species richness in summer and fall when compared to NRs. However, although species richness was higher on ARs in the summer, evenness was similar to that on NRs (Shannon *t*-test, $P > 0.05$). The data from Wen *et al.* (2010) showed

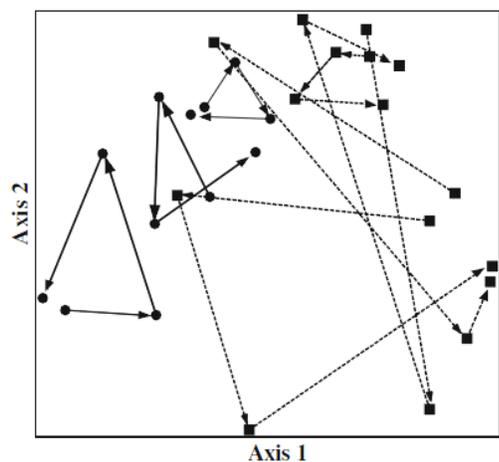


Fig. 1. Temporal shift in fish communities at natural and artificial sites. Successional vectors connect consecutive sampling seasons (in series as fall, winter, spring, summer). Solid line and circles: natural coral patches; dashed line and squares: artificial reefs (Burt *et al.* 2009).

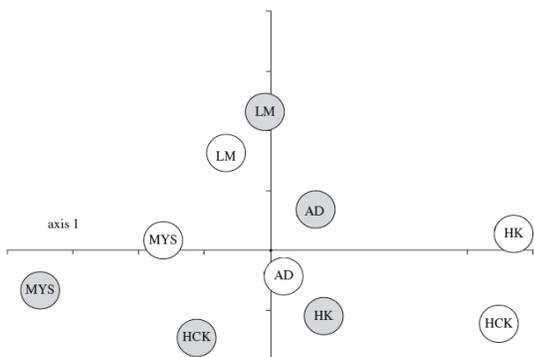


Fig. 2. Canonical discriminant analyses of coastal fish assemblages in summer, comparing community structure between anthropogenically modified (●) vs. natural habitats (○), at five locations; Ao-Di (AD), Lon-Men (LM), Mei-Yan-Shan (MYS), Hai-Ko (HK) and Hong-Chai-Keng (HCK). (Wen *et al.* 2010)

similar results, indicating no significant differences in species richness between habitat types. Significant temporal variation was not evident. Finally the study of Arena *et al.* (2007) showed that there were significantly more species on ARs than on NRs ($P < 0.05$, ANOVA). Interestingly, unlike the other studies, there was a linear relationship between mean species richness and the age of the AR ($R^2 = 0.06$, $P < 0.05$; Arena *et al.*, 2007).

Assemblage structure

Burt *et al.* (2009) showed a temporal shift among species associated with each habitat type using an indicator species analysis. The Analysis only shows species specific preference for one habitat type (i.e. AR or NR) in the summer and the fall of sampling period. The ordination of fish communities associated with habitat types indicated a significant difference ($P < 0.05$). Habitat type significantly explained 49% of the variation in fish communities between ARs and NRs. In support of the ordination results, a multi-response permutation procedure (MRPP) analysis also showed significant difference in community structure between habitat types ($P < 0.05$). There were substantial differences in the amount of community change over the year on ARs and NRs (Fig. 1). Natural reefs indicated limited change in fish communities between seasons, whereas in ARs substantial changes were seen throughout the sampling period. Greatest differences between ARs and NRs could be seen in fall and summer, when AR communities diverged from NRs, and converged back toward NR communities during the winter or spring (Fig. 5). Further ordination analyses showed similar results, showing significant differences in fall and summer between the habitat types ($P < 0.01$ and $P < 0.05$; respectively).

The community structure observed by Wen *et al.* (2010) showed significant difference between habitat types, despite limited variation in species richness. However overall assemblages of fish communities of habitat types in summer, pooled together from the five different sites, were not differentiated (Fig. 2). Two of the five locations showed strongest dissimilarities during the summer (location Hai-Ko and Hong-Chai-Keng). In the winter, however, distinction between the overall ARs and NRs was more pronounced. There were strong similarities between habitat type, despite location (Fig. 3). The locations with the oldest AR (locations Ao-Di and Mei-Yan-Shan) showed the most pronounced differences when compared to NRs.

The results of the multidimensional scaling in Arena *et al.* (2007) showed distinct differences in fish assemblages between ARs and NRs (Fig. 4). The highest dissimilarities (SIMPER analysis: 69% dissimilarity) between ARs were found when comparing the oldest and the youngest of the ARs.

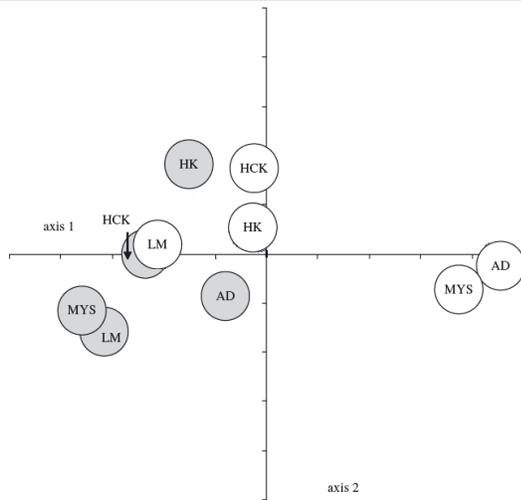


Fig. 3. Canonical discriminant analyses of coastal fish assemblages in winter, comparing community structure between anthropogenically modified (○) v. natural habitats (●), at five locations; Ao-Di (AD), Lon-Men (LM), Mei-Yan-Shan (MYS), Hai-Ko (HK) and Hong-Chai-Keng (HCK). (Wen *et al.* 2010)

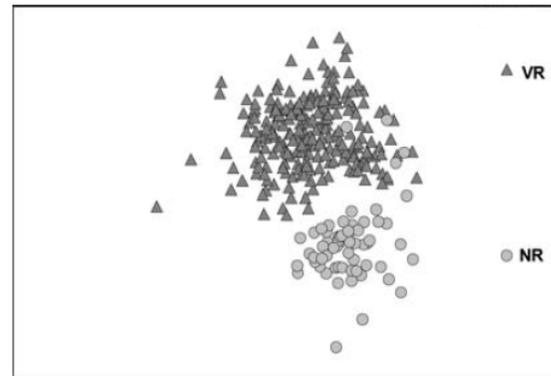


Fig. 4. MDS plot of Bray-Curtis dissimilarity indices of artificial and natural reefs. VR = artificial reef; NR = naturalreef (Arena *et al.* (2007)).

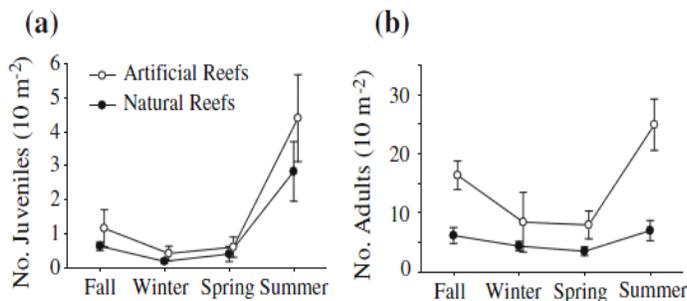


Fig. 5. Abundance of (a) juvenile, and (b) adult fish on natural and artificial habitats during each sampling period (mean \pm SE). (Burt *et al.* 2009).

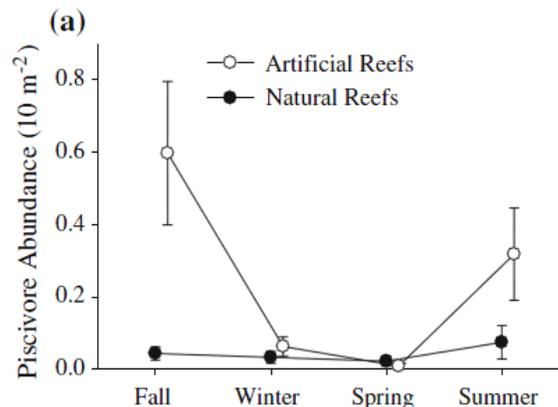


Fig. 6. Changes in abundance in predatory fish on natural and artificial habitats over the sampling year (mean \pm SE). (Burt *et al.* 2009).

Furthermore, Burt *et al.* (2009) examined juvenile and adult variation among the seasons. For both ARs and NRs, juvenile abundance increases in the summer significantly (Fig. 5; Two-way ANOVA between season and habitat type indicated seasonal change was significant: $F_{(3,27)} = 20.1$ $P < 0.001$), but no significant difference was calculated between the two habitat types. Adult abundance of fish showed significant difference between sampling periods and habitat types (Fig. 6; Two way ANOVA $F_{(3,27)} = 9.9$ and $F_{(1,27)} = 18.1$, respectively, $P < 0.001$). Although on NRs adult abundance did not differ significantly among sampling periods, on ARs adult abundance increased significantly in the summer when compared with winter and spring (Fig. 6; ANOVA $F_{(3,12)} = 8.7$, $P < 0.01$). Further examinations of Burt *et al.* (2009) focused on the role of predation, hence abundance of piscivorous fish was also observed. Natural reefs showed no variation throughout the sampling period, unlike ARs which had an increase in piscivorous fish abundance in the summer. Artificial reefs showed significantly higher abundance of piscivores compared to NRs (ANOVA $F_{(1,33)} = 8$, $P < 0.01$).

Arena *et al.* (2007) also examined juvenile abundance of fish on ARs and NRs. It was found that on ARs the abundance of juvenile fish was significantly greater on ARs when compared to NRs (ANOVA $P < 0.05$). Arena *et al.* (2007) conducted a more extensive examination and also looked at fishes that are planktivores, benthic carnivores, herbivores and piscivores; all of which were significantly different between ARs than NRs except omnivorous fish, which showed no significant variation (Fig. 7).

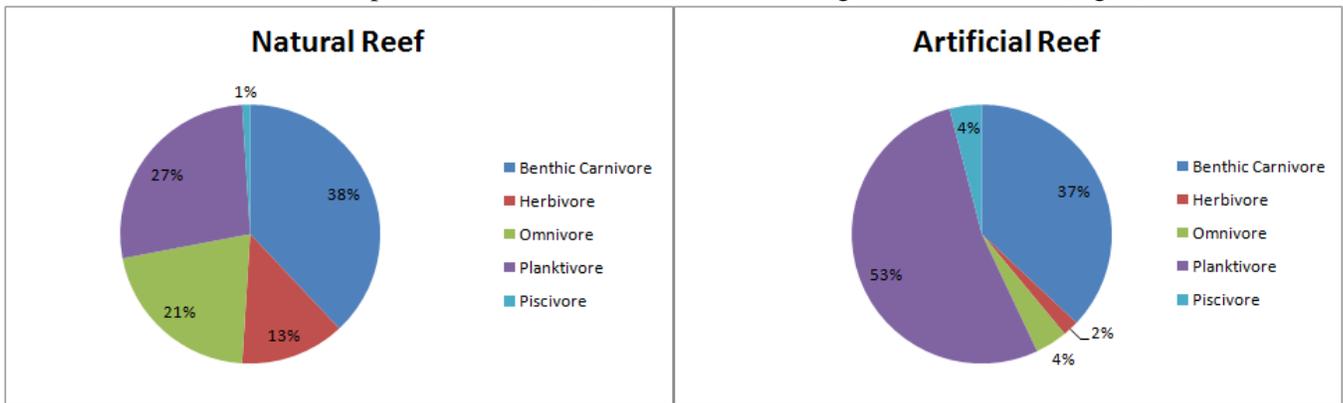


Fig. 7. Trophic composition as a percent of total fish abundance on vessel- and natural reefs. All trophic levels differed significantly from each other, except omnivores. (Arena *et al.* 2007).

Habitat Complexity

The previous studies have shown that fish abundance, species richness and fish assemblage per habitat types can differ. But none of them have assessed what governs those differences. A study by Gratwicke and Speight (2005) did just that. During the study, differences in fish abundance and species richness were measured while simultaneously assessing characteristics of the habitat. A habitat assessment score (HAS) was made, characterizing the habitat in 6 different components: Rugosity, variety, height, refuge size categories, live cover and hard substratum (Table II). A higher HAS indicates a more complex habitat. By using the HAS the authors tried to determine which variables were the most important in predicting fish abundance and species richness. Hereby they described spatial variation in habitat complexity parallel to fish abundance and species richness. The study area on the shore of Tortola, a 61 km² island of the British Virgin Islands in the Caribbean, was characterized by coral, seagrass, algae and sandy patches and samples were retrieved in the summer of 2001.

The combination of the sum of all habitat complexity variables accounted for 71% of the variation in observed species richness and 22% of the variation in total habitat. Of the 6 HAS variables only 2 were positively correlated with observed species richness i.e. rugosity and variety of growth forms. For total fish abundance the only significant predictor was height.

Sandy stations were generally less complex and had fewer species than algal and seagrass beds, which in turn were less complex and had fewer fish species than reefs. Interestingly, species richness in relationship to habitat complexity (i.e. the slope of species richness as complexity increases) within habitats showed no difference when comparing the different habitat types (i.e. coral, seagrass algae and sandy patches). In contrast, habitat complexity did, indicating that complexity variables are responsible for the observed variations, and not the habitat type itself, in fish species richness and to a lesser extent fish abundance.

Discussion

The studies reviewed in this thesis have shown that there was no clear definable distinction between ARs and NRs in terms of fish abundance and species richness. Wen *et al.* (2010) showed no significant difference in fish abundance between the habitat types, contrasting the results of Arena *et al.* (2007).

Strangely though, different authors have found that artificial reefs generally contain higher fish densities than adjacent NRs (Abelson and Shlesinger 2002). They also tend to support distinct assemblages that differ in species composition (Clynick *et al.* 2008), and ARs generally contain more species of fish than is observed on NRs (Perez-Ruzafa *et al.* 2006). This corresponds with the results of Burt *et al.* (2007), whom also found higher fish abundance and species richness on ARs, and a different community composition from natural habitats, but only during certain seasons.

There seems to be an inconsistency among the data present in contemporary literature. This could be a consequence of the comparative means of conducting research as applied in the papers discussed. The comparative studies discussed fail to recognize processes that could influence *in situ* observations of species composition, abundance and diversity. The authors omit any reference to a theoretical framework, thus the papers lack true scientific merit. Sufficient evidence is present to support the hypotheses that young ARs are currently in a pioneer stage and that ARs are still oscillating towards equilibrium. Hence, most comparisons would be biased as they are unable to factor in that ARs and NRs are in different phases.

For example, artificial reefs tended to show more temporal variation than NRs, especially in summer, when adult populations tended to increase dramatically (Fig. 5; Burt *et al.* 2009; Wen *et al.* 2010). Throughout the sampling period fish communities on NRs maintained a fairly stable state whereas ARs were dynamic (Burt *et al.* 2009). Interestingly enough, artificial habitats indicated a linear relationship between the age of the AR and the amount of species present (Arena *et al.* 2007). As the AR reef increased in age so did the amount of species. Furthermore, the SIMPER analyses in Arena's (2007) study showed that the oldest AR (Unnamed Barge) showed greatest similarity to nearby NRs.

None the less comparative studies do provide insights whether or not the two habitat types resemble each other. Fish community structures and thus species present differed in all the three comparative studies. As Burt *et al.* (2009) stated so well, artificial reef "are not surrogates of natural habitats".

The authors of the articles reviewed provided insights what biotic and abiotic factors could be influencing the marked differences between the two habitat types. The role that habitat structure has on fish communities is known (Gratwicke and Speight 2005), and could well be influencing the differences in taxonomic composition in fish assemblages in AR and NR habitats. Furthermore, Hutchinson's (1957) concept of niche availability predicts that with a greater variety of potential niches more species can coexist. This concept is reflected by the fact that the more complex a habitat was, the more species it supported (Gratwicke and Speight 2005). The authors showed that 71% of the variation in species richness and 22% in fish abundance can be explained by the HAS index. The variety in habitat can offer a variety of resources e.g. food type, camouflage, refuge spaces or breeding sites (Gratwicke and Speight 2005). Also, the increase in variety of refuge sizes would also provide a greater range of species to utilize them. In general the patchy nature of species richness and fish abundance is reflected by the patchy nature of habitat complexity, regardless of habitat type (i.e. sandy, seagrass, coral, breakwaters, vessels etc.). In

the end the extent to which ARs support a greater or lesser number of fish abundance and species depends on differences in the availability of specific niches certain habitat types can provide.

Niche diversity could also influence predator-prey interactions. It is often the availability of habitat that regulates the abundance of fish and especially the presence of predator refuge v. availability of prey (Sale, 1980). In general, ARs are less complex and thus have less refined hiding spaces available for smaller fish species hereby attracting species that make use of larger shelter holes. Species utilizing ARs as resting sites and shelters between foraging events at their natural habitats could experience a decrease in energy expenditure as risk of predation decreases (Arena *et al.* 2007). Although Burt *et al.* (2009) found that piscivorous fish abundance was highest on ARs. These high numbers in piscivorous fish could be the direct result of increased prey availability.

When looking at the community structure of the fish assemblages, all the three studies indicated a significant difference between ARs and NRs. Wen *et al* (2010) hypothesized that this is due to the difference in habitat structuring. Indicating that it is not large scale processes and regional species abundance but rather the habitat structure, i.e. habitat complexity, that influences species composition. These results correspond with those found during the habitat complexity study (Gratwicke and Speight 2005), reinforcing the fact that although no marked changes in abundance and diversity of fishes between ARs and NRs are observed, marked changes in taxonomic composition are still possible.

So far, it seems that habitat complexity is the governing factor in determining the assemblage of fish species. In order for offshore wind farm foundations to resemble nearby NRs, they should focus on mimicking the habitat complexity. In an earlier study Langhammer and Wilhelmsson (2009) tried to utilize the foundations of offshore wind farms as ARs. They found that the foundations of wind farms do indeed attract fish. The fact that fish aggregate to underwater structures in an otherwise barren landscape is not new. However, Langhammer and Whilhelmsson (2009) did try to create a more complex habitat by adding holes in the foundations and comparing them to foundations lacking complexity. Ultimately they

Table II. Habitat assessment score (HAS) sheet for near-shore coastal habitats, copied on to the back of an underwater slate. The HAS score for each category was assessed visually in each quadrant and recorded with the fish data. (Gratwicke and Speight 2005).

	HAS SCORE				
	1	2	3	4	5
Rugosity (visual topographic estimate of the substratum in each quadrat)					
Variety of growth forms (stalked/lobed/filamentous/ribbon-like/massive/branching/cylindrical/tube/fan/plate/pinnate/encrusting/other)	<2	3 & 4	5 & 6	7 & 8	9–10
Height (visual estimate of average height of habitat architecture) (cm)	0–9	10–19	20–39	40–79	>80
Refuge size categories (holes or gaps in habitat architecture or substratum in the following size categories: 1–5, 6–15, 16–30, 31–50 and >50cm)	0–1	2	3	4	5
Live cover (total per cent cover of e.g. living corals, mangrove roots, seagrass, macroalgae and sponges)	0–19	20–39	40–59	60–79	80–100
Hard substratum (%)	0–19	20–39	40–59	60–79	80–100

found no significant interaction between species richness and habitat complexity. These results are not unlikely, since Gratwicke and Speight (2005) showed that habitat complexity cannot simply be increased by creating holes in flat concrete slabs. It is far more complicated, and thinking to increase complexity by adding holes is seriously underestimating the intricate role habitat complexity plays in defining fish communities.

If offshore wind farms are to attract a more diverse set of fish species, diversity must first be created in the slabs themselves. Using the HAS index would be a perfect tool to assess complexity of NRs. Although the HAS score explained 71% of the variation in species richness, which was mostly contributed to the habitat characteristic rugosity, there is still a lot unknown about what governs fish community structure on ARs.

Even though Langhammer and Whilhelmsson (2009) saw their study as a success, in terms of using offshore wind farms as ARs, the study was conducted only on the foundations of a windmill. Therefore, the results lack applicability because none of the known negative effects of windmills were taken into account. It seems unlikely that similar results would be seen with a fully operational and running windmill. Thus, the next step in determining if windmill foundations can be used as ARs, is to do a study on an operational windmill farm.

There is little doubt that the foundations of offshore windmill farms will attract biota. Therefore it is important in what setting the windmill parks are placed. Providing an AR in a pristine ecosystem would not only be redundant but could also have adverse effects on the surroundings. We have seen that the ARs can support a unique composition of fish species. Herein lays the danger, by providing a distinct habitat species composition throughout the entire system could change. If windmill foundations are placed in a barren landscape, than potential negative effects on its surroundings would be minimized. Thus, the degree to which ARs should mimic natural surroundings would be a direct result of what the potential loss could be if the AR attracts a different composition of species.

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Cover Picture: <http://pangaea-yep.com/blogs/entry/ARTIFICIAL-REEFS-Are-they-the-Answer->

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